



## Digital receiver and signal processor for enhanced radar data

ENIGMA V is the latest generation of the popular and advanced weather radar signal processor for single and dual polarization developed by GAMIC. It consists of a host (ENIGMA PC) and a completely redesigned IFD (intermediate frequency digitizer). The IFD converts your radar output to a stable and high quality digital signal while the host provides clean output data by applying powerful algorithms and corrections.

### THE NEXT GENERATION OF SIGNAL PROCESSING

The ENIGMA V signal processor is suitable for **magnetron, klystron, or solid-state radars**. In case of coherent-on-receive radars, the IFD is able to measure the IF frequency and apply an **AAFC (adaptive automatic frequency control)** for proper reception. A sliding window matched filter reduces STALO-control activity to a minimum, resulting in an improved estimation of coherent physical moments.

ENIGMA V is the perfect match for solid-state weather radars. Thanks to its **massive processing power** and **improved waveform generation** ENIGMA V can perform pulse compression with much more complex signal coding/decoding and solid-state pulse schemes. **Pulse compression** is a radar technique that combines the advantages of long and short pulses. ENIGMA V uses NLFM (Non-linear Frequency Modulation) technique in order to **reduce side lobe levels and improve range resolution**. This is critical for weather radar systems due to the high dynamic range requirement. Additionally, a frequency-diversity pulse scheme is implemented to avoid contamination of echoes of the different subpulses. ENIGMA V has four real or two complex **waveform generators which are freely programmable** (up to 900MHz sampling rate), allowing **optimal pulse waveform** to improve ground clutter suppression and weather detection while reducing false detection of weather echoes.

### GET THE BEST OUT OF ANY WEATHER RADAR

The IFD V controls the transmit timing of the connected radar by applying trigger signals and performing the data acquisition accordingly. It comes with six input channels: two horizontal, two vertical, and two burst (transmit signal / reference) which enable **full dual polarization capability**. The IF signal is digitized at an intermediate frequency of 60MHz (others optional) and the radar echo data is tagged with corresponding time and elevation/azimuth angle information. For **optimum sensitivity and dynamic range** a digital filter is applied which matches the transmitted pulse length perfectly.

The generated raw echo data is provided to the host PC through an optical fibre connection of 10Gbit/s for further processing. Maintenance and control are improved with even **more BITE information** (monitoring of input signals, temperature values, supply voltage, etc.), accessible remotely and via a USB connection or 1 Gbit/s ethernet port.

### COMPACT FORM FACTOR & IMPROVED RACK MOUNT

The ENIGMA V signal processor comes with a complete hardware redesign. The new IFD V is available as an **easily integrable and flexible version** (e.g. for head-mount installations) or as an **improved and shorter 19" rack mount version** with high efficiency (power consumption <50W) and focus on reliability optimizations, such as cooling, utilization of conductive polymer electrolytic capacitors, electrostatic discharge protection, and supply voltage distortion filtering.

### Features

- » Weather radar signal processor for rapid scanning and analysis of scientific quality and accuracy
- » Compatible with **magnetron, klystron, and solid-state radars**
- » **Digital Doppler processor-receiver** with pulse compression
- » **Powerful correction and mitigation** of clutter, interferences, multi-trip echoes, and many more
- » **Comprehensive output data**

### Technical details

- » Intermediate frequency digitizer (IFD) and host
- » IF frequency of 60MHz (others optional)
- » Typical dynamic range: >110 dB
- » Typical base resolution: 25–125 m
- » Range: 10–400 km
- » PRF: 10–3000 Hz
- » Up to 8,000 range bins
- » Host with standard rack mount
- » IFD optionally with rack mount



IFD V rack mount front and back view



IFD V for smooth integration

### POWERFUL PROCESSING & CORRECTION ALGORITHMS

Digital Doppler velocity processing enables **more accurate velocity data and better clutter mitigation**. The velocity based clutter filters provide more than 50dB clutter rejection, resulting in less ground clutter. Dual polarization based **rain and gas attenuation correction** are inevitable for reliable rain rate retrievals, especially for sensitive X-band radars. Further data improvement features comprise the **removal of multi-trip echoes, RF interferences, and sun spokes**.

ENIGMA V is highly configurable, including speckle remover (via reflectivity, velocity, spectrum width, or dual polarization moment), thresholding (NOISE, CCOR, SIGPOW, RHOHV, SQI), and KDP interpolation. The following efficient ENIGMA software algorithms ensure best data quality and reduce disturbances:

- » **Fuzzy logic classification and flagging** of range gates for ground clutter, multi-trip echoes, RF interference, and sun spokes
- » **Improved random phase multi-trip detection** and mitigation
- » **Adaptive clutter filtering**
- » **Additional output moments** (clutter phase alignment, standard deviation, SQI, 2nd/3rd trip, classification flags, real and complex cross spectrum)
- » **Improved thresholding** including the new classifier flags
- » **Wind turbine clutter detection algorithm** (see box below)

### COMPREHENSIVE OUTPUT MOMENTS

Besides typical single polarization radar moments reflectivity (Z), radial velocity (V), and spectral width (W), ENIGMA V provides **output of enhanced dual polarization moments** which are essential for any contemporary processing and further usage of weather radar data. The output moments include ZDR, KDP, RHOHV, PHIDP, and many more. All radar moments are provided uncorrected and corrected.

For a **comprehensive data quality and signal analysis**, ENIGMA V serves output variables like signal-to-noise ratio (SNR), signal quality index (SQI), clutter power (CCOR), power spectrum (DFT), and more.

Other features and specifications	
<b>Time averaging</b>	Adjustable time samples (8–1024) or dynamic angle syncing
<b>Sector blanking</b>	32 configurable azimuth/elevation sectors (0.05° resolution)
<b>I/Q recording</b>	Pulse-wise, 32 bit IEEE floating point format to internal HD
<b>Configuration</b>	Frog-Muran network capable GUI, telnet, or built-in HTTP server
<b>Status output</b>	ASCII BITE and log messages via telnet port, HTTP server interface
<b>Status information</b>	Host (CPU load and temperature, memory usage, voltages) IFD (power supply, temperatures) Status of A/D converter, AFC, Sector blanking Number of pulses for auto-correlation
<b>Matched filter designer</b>	GUI application for semi-automatic calculation of matched filter coefficients (for transmitter pulse) and verification.
<b>AAFC</b>	Comprehensive AAFC (adaptive automatic frequency control) configuration and visualization

Intermediate frequency digitizer (IFD)	
<b>Receiver inputs</b>	6 channels (2×H, 2×V, 2×reference)
<b>Internal channels</b>	6×16 bit (2×H, 2×V, 2×burst)
<b>Frequency</b>	60 MHz (other optional)
<b>Dynamic range</b>	>110 dB @ 2 μs pulse width
<b>Power consumption</b>	<50 W (100–230 V, 50/60 Hz)
<b>Enclosure</b>	Compact easily integrable version or standard 19" rack mount

Host (ENIGMA PC)	
<b>Typical base resolution</b>	25–125 m
<b>Max. range bin resolution</b>	10 m
<b>Range</b>	up to 400 km
<b>PRF (pulse repetition freq.)</b>	10–3000 Hz
<b>Number of pulse widths</b>	4 with independent configurable matched filters (up to 1280 taps)
<b>Dual PRF modes</b>	None, 2/3, 3/4, 4/5, and more
<b>Processing modes</b>	PPP (pulse pair processing), FFT, DFT, staggered PRT
<b>Connection to IFD</b>	Fibre optic, 10 Gbit/s
<b>Power consumption</b>	<150 W (100–230 V, 50/60 Hz)
<b>Enclosure</b>	Standard 19" rack mount (3 or 4 HU), depth 420 mm or custom

Output data	
<b>Reflectivity</b>	Corrected Reflectivity (Z) Uncorrected Reflectivity (UZ) Attenuation Corrected Reflectivity (AZh)
<b>Doppler velocity</b>	Radial Velocity (V) Folded Radial Velocity (VF) Spectral Width (W)
<b>Signal analysis</b>	Clutter Power (CCOR) Signal Quality Index (SQI) In-Phase/Quadrature Signal (I/Q) Logarithmic Power (LOG) Signal Noise Ratio (SNR) Censor Map Power spectrum (DFT)
<b>Dual polarization</b>	RhoHV, PhiDP, KDP, ZDR Attenuation Corrected ZDR LDR (H-transmit) RhoH (H-transmit)
<b>New output moments</b>	Clutter Phase Alignment (CPA) Standard Deviation (SRD) SQI Second / Third Trip (SQI2/SQI3) Classification Flags (CLASS) Cross Spectrum (Real & Complex)

Data quality algorithms	
<b>Attenuation</b>	Rain and gas attenuation correction
<b>Range normalization</b>	1/r <sup>2</sup> range normalization
<b>Configurable speckle remover</b>	Reflectivity (2D), velocity, spectrum width, dual polarization moment
<b>Config. thresholding</b>	NOISE, CCOR, SIGPOW, RHOHV, SQI
<b>Multi-trip removal</b>	Second trip / third trip
<b>Interference removal</b>	RF interferences, sun spokes
<b>KDP interpolation</b>	Configurable (Gauss., B-spline, 0.125–5km)

### Wind turbine clutter (WTC) detection

Everyday more wind turbines are installed within the range of radar systems. An increasing problem appears in the evaluation of weather radar data due to dynamic wind turbine clutter. Addressing this problem, **ENIGMA V has a built-in WTC detection algorithm**. The example images show detected wind turbines as black pixels while original wind turbine locations are marked purple. GAMIC's WTC detection algorithm is **operational used by a major national weather service**.

